Sorensen
POWER SUPPLIES

instruction manual for F.R. SERIES AC LINE VOLTAGE CONDITIONERS

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ORENSEN COMPANY

A UNIT OF RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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MODELS

FR1015A	FR2515A	FR5015A
FR1016A	FR2516A	FR5016A
FR1025A	FR2525A	FR5025A
FR1026A	FR2526A	FR5026A

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SECTION I

INTRODUCTION AND DESCRIPTION

1-1 INTRODUCTION.

1-2 The Sorensen Company Series FR 1000, FR 2500, and FR 5000 AC Line Conditioners are versatile, compact, high performance units designed for laboratory and instrumentation systems use. The three series provide output power of 1kVA, 2.5kVA and 5kVA respectively. Each series includes models designed to accept input frequencies of 400 Hz, 50 Hz, or 60 Hz. The output voltage of each model is held constant over an unusually wide range of ±3 Hz. All models offer extremely fast transient recovery time of 50 microseconds, and distortion-free sine wave output. The all solid state circuitry generates harmonic voltages to cancel any harmonics present in the input power. The output, therefore, is not only regulated at the nominal output, but conditioned into a true sine wave, free from harmonics and power line transients.

1-3 The power input to the FR Line Conditioner is isolated from the output ground and the chassis ground. The output ground and the chassis ground are also completely isolated from each other. The double-shielded power transformer has less than one picofarad coupling capacitance between primary and secondary windings. Common mode voltages are, thereby, held to an extremely low value.

1-4 The FR Series AC Line Conditioners provide highly regulated AC output suitable for a variety of instrumentation and system applications. The line conditioners provide short circuit protection, regulated output over an input voltage range of 95 to 135 volts, or 190 to 270 volts, and visual power line monitoring with front panel mounted meter(s).

1-5 SCOPE OF MANUAL.

1-6 This manual describes the Sorensen Company FR Series of AC Line Conditioners. It contains operating and maintenance instructions, circuit descriptions, circuit diagrams, and parts lists. Circuits normally understood by operating technicians and field engineers and details of mechanical construction are not described.

1-7 DESCRIPTION.

1-8 The Sorensen Company FR AC Line Conditioners are contained in a rack-mount enclosure with metering for power line monitoring, an overload indicator, and a power circuit breaker located on the front panel. Cooling air is drawn through a front panel grill, and exhausted at the rear. A rear panel switch selects input voltage ranges from 95 to 135 VAC, or 190 to 270 VAC.

1-9 The enclosure contains similar power amplifiers, mounted on separate heatsink chassis. A silicon controlled rectifier, used as an overload bypass, is also mounted on a separate heatsink. Control circuitry is mounted on three plug-in circuit boards. Test points necessary for adjustment and maintenance are available at the top of the circuit boards. The double-shielded power transformer is located in the center of the enclosure, allowing stable weight distribution and complete electrostatic shielding.

1-10 INPUT CONNECTIONS. Terminal boards or binding posts are provided on the rear panel for input and output power. The FR 1000 series is equipped with three binding posts for output lo, secondary shield-chassis, and primary shield. Input power is by means of a three prong connector. The primary shield of the transformer is connected to the grounding pin of the power input plug, and to the primary shield post. The transformer secondary shield is connected to the chassis, to the grounding pin of the duplex outlets, and to the secondary shield post. The output low terminal is connected to the output-lo post. The FR 2500 and FR 5000 series provide terminal boards on the rear panel for the input and output power. The input power terminal board carries chassis ground and primary shield con-

nections as well as power high and low terminals. The output power terminal board provides output high and low terminals, remote sensing high and low terminals. secondary shield terminals, and an additional chassis ground terminal. In all cases, the instruments are shipped from the factory with the terminals jumpered to ground. The output low and secondary shield terminals are jumpered to ground, and the input primary shield is jumpered to chassis ground. For isolated ground operations, the grounding jumpers must be removed and appropriate grounding connections made. Some experimentation with ground connections may be necessary to achieve optimum circuit isolation.

1-10 Loads up to the maximum for a specific model may be connected at the rear panel. Table 1-1 shows the maximum KVA output power for the various models and gives the average load current required to initiate an overload condition. Some loads, such as incandescent lamps, motors, or some electronic instruments, draw starting surges which activate circuitry. Shortly after the starting surge has passed, the line conditioner resumes normal operation.

MODEL	MAXIMUM OUTPUT POWER	AVERAGE LOAD CURRENT/PEAK LOAD
1015A-1016A	1 KVA	Excess of 8 3/4 amps or 30 amps peak load.
1025A-1026A	1 KVA	Excess of 4.35 amps or 15 amps peak load.
2515A-2516A	2.5 KVA	Excess of 22 amps or 75 amps peak load.
2525A-2526A	2.5 KVA	Excess of 11 amps or 37 1/2 amps peak load.
5015A-5016A	5 KVA	Excess of 43 1/2 amps or 150 amps peak load.
5025A-5026A	5 KVA	Excess of 22 amps or 75 amps peak load.

Table 1-1. Loads and Currents Required To Initiate Overload Condition.

1-12 SPECIFICATIONS - GENERAL

MODEL		FR 1000 SERIES	FR 2500 SERIES	FR 5000 SERIES
Output Power		1 KVA	2.5 KVA	5 KVA
Dimensions:	Height	7 inches	14 inches	24½ inches
	Width	19 inches	19 inches	19 inches
	Depth	17½ inches	19 inches	20 inches
Weight:	NET	105 pounds	175 pounds	400 pounds
	Shipping	115 pounds	185 pounds	425 pounds

1-13 SPECIFICATIONS - PARTICULAR

MODEL	1015A 2515A 5015A	1025A 2525A 5025A	1016A 2516A 5016A	1026A 2526A 5026A
Input Voltage (VAC)	90-115 105-125 115-135	190-230 210-250 230-270	90-115 105-125 115-135	190-230 210-250 230-270
Input Frequency	50 Hz ±3 Hz		60 Hz ±3 Hz	
Output Voltage	115 VAC Nominal Adj. to 110-120 VAC	230 VAC Nominal Adj. to 220-240 VAC	115 VAC Nominal Adj. to 110-120 VAC	230 VAC Nominal Adj. to 220-240 VAC
Output Harmonic Distortion	0.2% Maximum			
Load Power Factor	Full Current Rating - unity to ±0.7 pf Half Current Rating to 0 pf Leading or Lagging			
Regulation*	±0.05%			
Response Time	50 Microseconds Nominal			
Output Isolation	Less than 1 pf Input and Output			
Ambient Temperature	0-55°C			
Temperature Coefficient (Maximum %/°C)	0.005			
Drift**	±0.05%			

* ±9% Line Voltage Change and Full Load Change Combined.

** 24 hours - Constant line, load and ambient temperature.

SECTION II
OPERATING INSTRUCTIONS

2-1 INSPECTION.

2-2 The Sorensen Company FR AC Line Conditioners are completely aligned, calibrated, and tested at the factory prior to shipment. The instruments, therefore, are ready for immediate use upon receipt. The following checks should be made, however, to assure that the instrument has suffered no damage during transit.

a. Visually inspect the shipping container before accepting the package from the carrier. If extensive damage to the shipping container is evident, a description of the damages should be noted on the carrier's receipt, and signed by the driver of carrier agent. If damage is unpacked, a claim for concealed damage should be placed with the carrier. Notify the carrier immediately. The carrier claim agent will then prepare a damage report. The user should forward this report to the Service Department, Sorensen Co., 676 Island Pond Road, Manchester, New Hampshire, 03103. Sorensen will advise the user as to the action required to repair or replace the equipment.

b. Make a visual inspection of the shipment after removing it from the shipping container. Inspect the enclosure for dents, chips or other signs of obvious damage. Remove the cover and determine that the circuit boards are firmly seated in the proper position. Make certain that all terminal screws are in place.

2-3 INSTALLATION and OPERATION.

2-4 Install the Line Conditioner so that the flow of cooling air into the front panel grill and out of the rear panel grill is unobstructed. If the power amplifier becomes overheated, the overload circuit will be tripped causing the line conditioner to deliver unregulated power.

2-5 Connect the instrument to the appropriate power source. Power is connected to the FR 1000 series by means of a power cable terminating in a three prong plug. In the other models, power is applied through terminal boards or binding posts. The input power terminal board carries a chassis ground connection and primary shield connection as well as input power high and low terminals. The output power terminal board provides output high and low terminals, remote sensing high and low terminals, the secondary shield terminals, and an additional chassis ground terminal.

Note

The FR series instruments are shipped from the factory with the output low and secondary shield terminals jumpered to the ground, and with the input primary shield jumpered to chassis ground. For isolated ground operation, the grounding jumpers may be removed from the terminal boards and appropriate grounding connections made.

The remote sensing terminals permit precise monitoring of load regulation at the load.

2-6 With input and output power leads connected, set the rear panel tap switch to the proper voltage range for the available input power. Taps are provided for three ranges in each power source.

2-7 Connect any load up to the maximum for a given model at the rear panel output connector of the instrument.

2-8 Set the front panel POWER switch to ON. The green indicator lights when the power is on.

2-9 Observe that the red overload indicator is lighted for a period of approximately four seconds after power is applied to the line conditioner. When the red light is on, the overload circuit is functioning. After four seconds the conditioning circuits are in control of the output.

2-10 During operation of the line conditioner, the front panel meter continuously indicates the value of the output voltage. The input voltage may be measured at any time by pressing the INPUT VOLTS button on the front panel. Output load current may be measured by pressing the OUTPUT AMPS button on the front panel. If both buttons should be depressed simultaneously, the meter indicates output load current without damage to the meter circuits.

2-11 ADJUSTMENTS (values in parenthesis refer to models with 190-270 volt input).

2-12 Meter Circuit Adjustment. There are two basic types of adjustment of the meter circuit, depending upon the model in use. Since the FR 1000 series uses a single multi-purpose meter, the calibrating adjustments are slightly more complicated.

a. FR 1000 series: The front panel volt-ammeter readout has three adjustments for calibration. A variable-ratio transformer capable of 10 (or 15) amperes load current, an accurate AC voltmeter, and an accurate AC ammeter are required to adjust the meter circuits. The adjustment procedure is presented in the correct order necessary for successful meter calibration. Adjustment trimpots are shown in Figure 4-1.

1. Remove top cover from the line conditioner.

2. Apply AC power to the line conditioner through the variable-ratio transformer.

3. Set the transformer to provide 95 (or 190) volts RMS to the line conditioner.

4. At the line conditioner front panel, hold the INPUT VOLTAGE pushbutton depressed.

5. On the meter board, adjust 95 (or 190) volts trimpot R404 for correct meter indication.

6. Set the variable-ratio transformer to provide 135 (or 270) volts RMS to the line conditioner.

7. At the line conditioner front panel, hold the INPUT VOLTAGE pushbutton depressed.

8. On the meter board, adjust the trimpot R406 for correct meter indication.

9. Remove the variable-ratio transformer from the input power line; connect the line conditioner directly to the power source.

10. Connect a load of approximately four (or eight) amperes to the line conditioner output through the external AC ammeter.

11. At the line conditioner front panel, hold the AMPS pushbutton depressed.

12. On the meter board, adjust the AMPS trimpot R408 for a meter indication which agrees with the external AC ammeter reading.

b. FR 2500 and FR 5000 series: The front panel ammeter readout has one adjustment for calibration. An accurate AC ammeter is required to adjust the meter circuit. Adjustment trimpot is shown in Figure 4-2.

1. Remove top cover from the line conditioner.

2. Apply AC power to the line conditioner.

3. Connect a load of approximately 20 (or 40) amperes to the line conditioner output through the external AC ammeter.

4. On the mother board, adjust the AMPS trimpot R607 for a meter indication which agrees with the external AC ammeter reading.

2-13 Output Amplitude and Reference Phase Adjustment. The line conditioner output voltage amplitude and reference voltage phase angle are adjustable. A variable-ratio transformer, an oscilloscope (Tektronix 502 or equivalent), and an AC voltmeter are required when making these adjustments.

a. Output Voltage Amplitude Adjustment. The output voltage may be varied between 110 volts and 120 volts (or 220 volts RMS and 240 volts RMS). The line conditioner nominal output is 115 volts RMS (or 230 volts RMS). If the output voltage is set above the nominal, the center of the amplifier dynamic range is shifted upward reducing the over-voltage regulation range slightly. If the output is set below the nominal, the center of the amplifier dynamic range is shifted downward reducing the under-voltage regulation range slightly. Adjustment is accomplished as follows:

1. Remove the top cover of the line conditioner.

2. Connect AC power to the line conditioner.

3. Connect the AC voltmeter to measure the line conditioner output.

4. On the reference and amplifier assembly, adjust AMPLITUDE trimpot R255 for the desired voltage output.

b. Reference Voltage Phase Adjustment. To adjust the phase angle of the reference voltage, the following procedure is recommended:

1. Remove the top cover of the line conditioner.

2. Apply AC power to the line conditioner through the variable-ratio transformer.

3. Connect the oscilloscope probe to TP2 (red) on the driver board, and the oscilloscope ground to TP1(brown) on the power supply board.

4. Simultaneously adjust the variable-ratio transformer and phase trimpot R223 on the reference and amplifier board for minimum amplifier output.

Note

This is analagous to balancing an impedance bridge, in that both in-phase and quadrature phase voltages must be zero for a null. A perfect null cannot be obtained since the amplifier must generate some harmonic voltages to cancel the harmonics in the input power.

2-14 SPECIFICATION VALIDATION.

2-15 To validate the line conditioner specifications, the following equipment is required:

a. Variac, capable of at least 10 amperes output.

b. AC voltmeter (Weston 433 or equivalent).

c. Differential voltmeter (Fluke 803 or equivalent).

d. Oscilloscope (Tektronix 502 or equivalent).

e. Oscilloscope (Hughes Memo-Scope or equivalent).

f. Distortion analyzer (Hewlett-Packard HP 330B or equivalent).

g. Variable frequency power source.

Test point 2 (TP2) presents the amplifier output, which is the most senitive indication of any change in dynamic range or regulation. The presentation at TP2 is a complex wave. Any clipping of the wave peaks indicates that the amplifier has exceeded the dynamic range, and that the output is out of regulation.

2-16 Input Specification. The input voltage range and the input frequency range are verified with the same test set up:

a. Remove the top cover of the line conditioner.

b. Connect the probe of the oscilloscope to TP2, and the oscilloscope ground to TP1.

c. Connect the line conditioner power inout to the variac output.

d. Connect the variac input to the frequency power source.

e. Set the variable frequency power source at the nominal frequency for the line conditioner model under test.

f. Set the variac at the nominal input voltage for the line conditioner model under test.

g. Vary the input voltage between 105 volts RMS and 125 volts RMS (or 210 volts RMS and 250 volts RMS).

h. Observe that there is no clipping of the sine wave displayed on the oscilloscope CRT.

i. Repeat steps g and h with the variable frequency power source at three cps below nominal frequency for the line conditioner model under test.

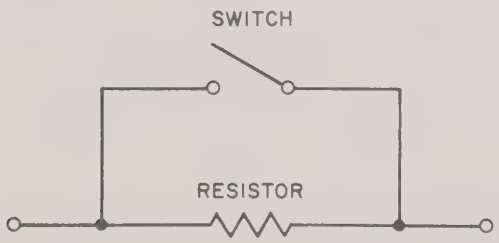
j. Repeat steps g and h with the variable frequency power source at three cps above nominal frequency for the line conditioner model under test.

k. Connect the line conditioner output to an appropriate resistance load.

l. Repeat steps g through j while observing there is no clipping of the amplifier output.

2-17 Response Time. The response time is measured by generating a line or load transient while graphically recording the output waveshape.

a. Connect a switch and an appropriate resistor (selected from the chart below) between the variac output and the line conditioner power input (see Figure 2-1).



FR 1000 series - 0.5 ohm, 50 watt
FR 2500 series - 0.2 ohm, 125 watt
FR 5000 series - 0.1 ohm, 250 watt

b. Connect an appropriate resistive load (see Table 1-1) to the line conditioner output, through a single pole, single throw switch.

c. Connect the Hughes Memo-Scope or equivalent to the line conditioner output.

d. Put the Memo-Scope in storage mode.

e. Operate the line switch and the load switch several times, in random fashion, to generate line and load transients.

f. Measure the recorded variations from a true sine wave output.

2-18 Load Regulation.

a. Connect the high resolution voltmeter to the line conditioner output.

b. Measure the output with nominal input voltage.

c. Vary the input voltage to lower and upper limits.

d. Verify that the output voltage reading does not change by 0.05%.

e. Connect an appropriate resistive load (see Table 1-1) to the line conditioner output through a switch.

f. Using the Fluke 803 differential voltmeter or equivalent, measure the output voltage at no load and at full load. The output voltage variation does not exceed 0.05%.

Note

When switching the output to full load, verify that the input line voltage to the line conditioner does not vary. If the input voltage changes, restore it to the proper value before measuring the output voltage.

2-19 Output Harmonic Distortion. Harmonic distortion in the line conditioner output is measured with an HP 330B Harmonic Distortion Analyzer or equivalent. For such low values of harmonic distortion as displayed by the Sorensen FR Line Conditioners, the null should be observed with an oscilloscope.

SECTION III

PRINCIPLES OF OPERATION

3-1 GENERAL.

3-2 The Sorensen Company FR AC Line Conditioner operates as an operational amplifier to slave the output voltage to an internally generated, stable, harmonic free AC reference voltage. The majority of the output power is supplied directly to the output by the shielded transformer. The amplifier, therefore, is electrically located in series with the transformer output to supply the difference power, boosting or bucking the transformer voltage to correct the output.

3-3 BLOCK DIAGRAM DESCRIPTION.

3-4 A block diagram of the FR AC Line Conditioner is shown in Figure 3-1. Input power is applied to the primary of a double-shielded step-up transformer. The transformer has two secondary windings: one supplied the high current power supplies and reference signal, the other provides the power output. The transformer shielding allows less than one picofarad capacitive coupling between the primary and secondary windings.

3-5 The reference voltage is generated from a sample of the AC input voltage, taken from the transformer secondary. The sample is passed through a phase control servo and phase comparator which compensate for any phase variation in the reference filter. The phase comparator compares the phase of the reference voltage with the phase of the input sample. The phase control servo, operated by the error signal output of the phase comparator, adjusts the phase of the input sample to maintain the reference voltage 180° out of phase with the output voltage from the transformer secondary winding.

3-6 The phase servo output is clipped in the square wave generator circuit to develop a symmetrical square wave. The amplitude of the square wave is adjusted by the zener diode amplitude comparison circuit. The square wave is filtered in the active filter to remove all harmonics. Filter output is a stable, pure AC sine wave reference signal. The reference signal and the regulated output are composed in summing resistors R234 and R235. The difference output at the summing junction drives the error amplifier.

3-7 The error amplifier consists of a tuned preamplifier, sharply peaked at the input power frequency, phase splitting circuits, positive and negative error signal drivers, and power amplifier output. The output of the power amplifier adds to the transformer output or subtracts from it, to maintain a pure sine wave output at the required voltage amplitude.

3-8 CIRCUIT DESCRIPTION.

3-9 The appropriate schematic diagram of the line conditioner circuits should be used with the following descriptions.

3-10 POWER INPUT CIRCUIT.

3-11 AC power is applied either through the input power cord (FR 1000 series) or to the input terminal board (all other models), and circuit breaker S1. The input power is applied to the primary winding of double-shielded power transformer T1, through tap switch S2. Switch S2, mounted on the rear panel, permits operation at 115 VAC with various input voltage levels. The ventilation fan is operated from the 115 volt tap of the transformer primary winding to insure proper operating voltage for the fan motor, irrespective of the tap position of S2.

3-12 LINE CONDITIONER GROUND CIRCUITS.

3-13 The double shielded power input transformer presents sub-picofarad capacitance coupling between primary and secondary circuits, allowing very little common mode current to flow in the ground circuits.

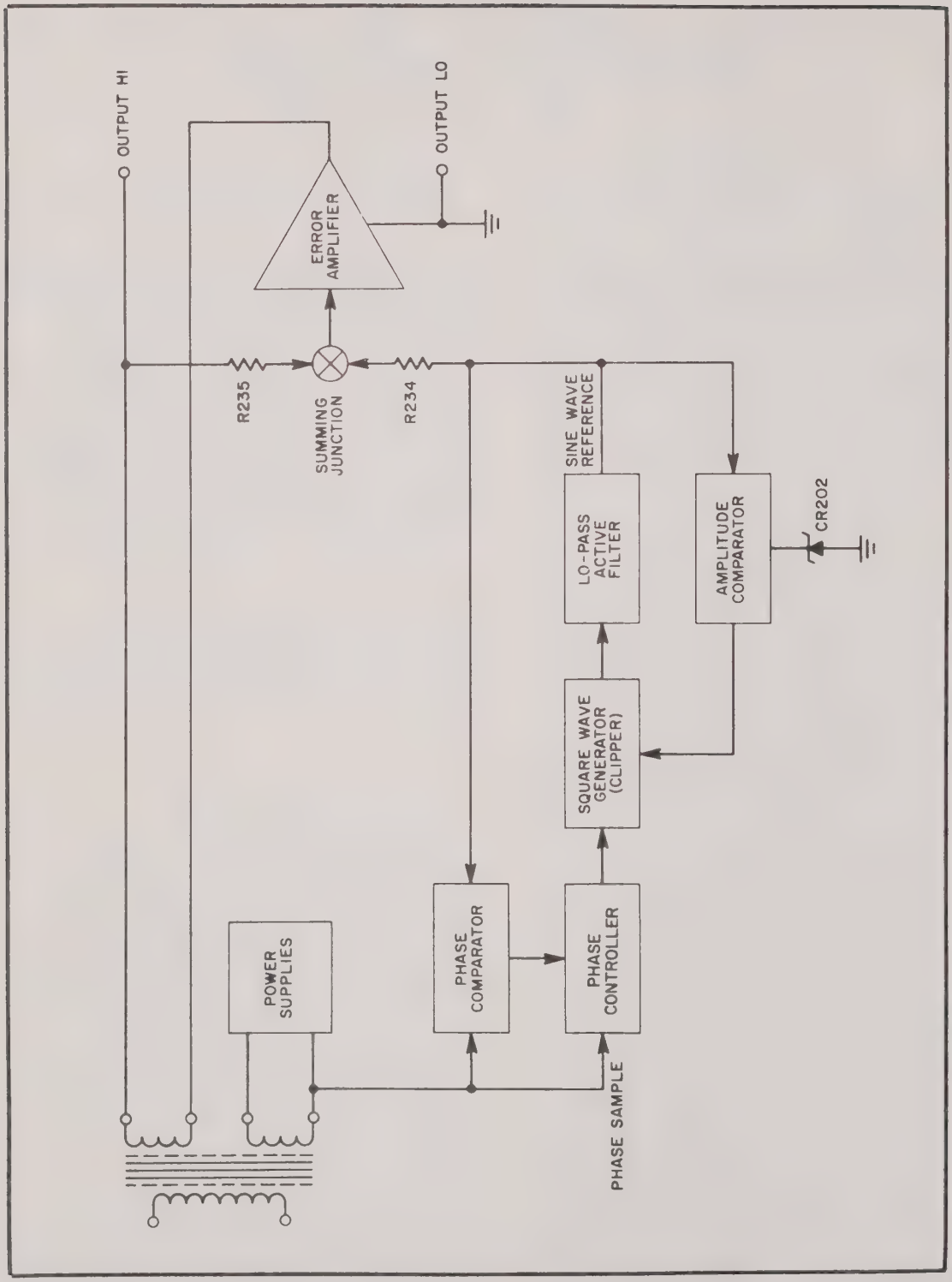


Figure 3-1. Block Diagram.

3-14 Since minor variations exist in the wiring of the ground circuits in the FR 1000 series and the other models, the differences will be covered in separate paragraphs.

Note

Different schematic symbols are used for chassis ground and regulator ground to indicate that the two grounds are separate and isolated from each other.

a. FR 1000 series. The primary shield is connected to the grounding pin on the input power connector and to PRIMARY SHIELD terminal J5 on the rear panel. The secondary shield is connected to chassis ground and sec shield CHASSIS terminal J3 on the rear panel. The output LO terminals of output connectors J1 and J2 are connected to regulator ground and OUTPUT LO terminal J4 on the rear panel. The regulator ground floating completely isolated from chassis ground and primary shield ground can be connected to an instrumentation ground to avoid common mode voltage problems in the instrumentation equipment.

The instrument is shipped with the three grounds strapped together at the three rear panel terminals. The strap is provided as a safety device and may be removed when the unit is installed.

b. FR 2500 and FR 5000 series. The input power terminal board is provided with a chassis ground connection and a primary shield connection as well as input power high and low terminals. The secondary shield is connected to a separate post on the output power terminal board. The primary and secondary shield terminals are jumpered to chassis ground. The jumpers are removed if isolated ground operation is desired. The regulator ground and secondary shield ground can be connected to an instrumentation ground to avoid common mode voltage problems in the instrumentation equipment.

3-15 REMOTE SENSING.

3-16 The FR 2500 and FR 5000 series provide remote sensing terminals on J4 to improve load regulation by sensing the output voltage directly at the load. To use remote sensing, remove the jumpers from Output Hi to Sense Hi and Output Lo to Sense Lo. Connect the Sense Hi terminal by a separate wire to the high side of the load and the Sense Lo terminal by a separate wire to the low side of the load. Do not operate the line conditioner with the sensing leads disconnected or reversed.

3-17 TRANSFORMER SECONDARY CIRCUIT.

3-18 The double-shielded input power transformer T1 has two secondary windings. The winding between pin 5 and pin 7 provides the power output. The transformer has step-up voltage characteristics to overcome the voltage losses in the regulator circuits. Windings between pins on the secondary provide positive and negative voltages to the power supplies, and to the primary windings of the low voltage transformer T2. The following chart shows the pin numbers and voltages supplied in each model.

MODEL	PINS	VOLTAGE
1015A,1016A, 5015A,5016A	8 and 11	45 volts
1025A,1026A, 2525A,2526A 5025A,5026A	9 and 11	90 volts
2515A,2516A	9 and 13	45 volts

Driving the primary of T2 from the secondary of T1 shields T2 from the primary power source. Power transformer secondary tap 10 and resistors R1,R2,R12 and R15 supply part of the load current at full load condition. The amplifier, therefore, is not required to carry full load current. If load current is less than the current supplied by the resistors, the amplifier accepts the difference. Resistors R1,R2,R12 and R15 reduce amplifier dissipation in full load conditions. The amplifier, as shown in the block diagram, is electrically connected in series with the power transformer secondary winding. Resistors R3, R4 and R7, and capacitor C2 are connected across the transformer winding to equalize transformer leakage reactance. The feedback loop through the transformer winding forms an M-derived filter. Resistors R3,R4 and R7 reduce the Q of the resonant circuit in the feedback loop, and capacitive bypass C2 balances the feedback loops when operating with a capacitive load.

3-19 METER CIRCUIT.

3-20 The three FR series differ in that the FR 1000 series employs a single meter to monitor three separate functions; the FR 2500 series has two front panel mounted meters; and the FR 5000 series uses three front panel meters. Consequently, the series models will be covered separately.

a. FR 1000 series. The instrument has one front meter panel used for three functions: input voltage, output voltage, and load current. An expanded-scale arrangement is used in the voltmeter circuits. Diodes CR401 through CR404 form a rectifier bridge which drives zener diode CR405 and a voltage divider bridge to provide voltage-scale expansion. At 95 (or 190) volts the bridge is nulled by the zener, causing the meter to indicate zero. The voltage across the current sensing resistor, R9, is sensed in transformer T3, stepped up and rectified by diodes CR406 and CR407 for the current indication on the front panel meter. Trimpot R408 is used to calibrate the sensitivity of the current indication.

Note

When adjusting the meter circuit, the high-voltage adjustment is performed after the low-voltage adjustment has been correctly set; e.g.: the 135 volt adjustment after the 95 volts (and the 270 volts after the 135 volts).

b. FR 2500 series. The instrument has two front panel meters used for input voltage, output voltage, and load current. Meter circuits are mounted on the motherboard. A front panel switch allows the voltmeter to display input voltage or output voltage.

c. FR 5000 series. The instrument has three front panel meters used for inout voltage, output voltage, and load current. The ammeter circuit is mounted on the motherboard.

3-21 REFERENCE and AMPLIFIER ASSEMBLY.

3-22 The reference input, taken from the power transformer secondary, is applied to the phase servo and the phase comparator. In the phase comparator, the phase of the reference input sample is compared to the phase of the reference output in a phase detector. Transistors Q212 and Q213 form an OR gate which clamps the junction of resistors R228 and R229 to ground when either input to the OR gate is positive. The signal at the junction of the two resistors is a variable duty ratio pulse, which is filtered by resistors R224 and R228, and capacitors C208 and C210. The DC voltage output of the filter is applied to the base of transistor Q208, which compares the DC at the base to the DC voltage applied to the emitter. As long as the base of the comparator is more positive than the emitter, the transistor is off. Any phase error causes the transistor to conduct. The output of Q208 is amplified in Q207, which drives the photocell. Altering the resistance of the photocell adjusts the phase of the reference input sample in the phase servo.

3-23 The corrected phase signal is applied to one input of integrated circuit Z201, which is over driven. Z201 clips the positive and negative peaks of the input sine wave. Transistor Q201 provides an additional squaring and phase inversion. The amplitude of the square wave is controlled by adjusting the collector supply voltage of transistor Q201. The reference output sine wave from transistor Q211 emitter is applied to half-wave rectifier Z203 via C220 and R273. The 180°-shifted half-wave d.c. voltage developed by Z203 is summed with the sine wave voltage (from resistor R272) at input pin 2 of integrator Z202. This results in a full-wave d.c. input voltage to Z202. The output of Z202 (pin 6) is a low-rippled d.c. voltage proportional to the reference output sine wave at Q211 emitter. The d.c. level at the output of Z202 is adjustable via AMPLITUDE potentiometer R267 which is supplied by reference zener CR208. Thus, if the reference output sine wave increases, the d.c. output level of integrator Z202 decreases, thereby controlling the amplitude of the square wave.

3-24 The square wave output of Q201 is directly coupled into emitter follower transistor Q203, which supplies low source impedance for the active filter.

The active filter consists of transistors Q204, Q205, Q206, Q209, Q210 and Q211, with associated filter capacitors and resistors. Thermal drift in the filter is corrected in the phase servo and square wave amplitude circuit- The output of the active filter is connected to the reference preamplifier through emitter follower Q211.

3-25 PREAMPLIFIER.

3-26 The preamplifier circuit is located on the reference and amplifier board. The reference signal is compared to the regulated output signal in summing resistors R234 and R235. The error signal from the summing junction is applied to emitter follower transistor Q214 of the preamplifier. The signal from the emitter follower is directly coupled to the base of transistor Q216, which drives emitter follower Q217. The output from Q217 is capacitively coupled to a second amplifier stage, consisting of amplifier Q218 and emitter follower Q219. The amplifier is sharply tuned at 60 Hz by bridged-T feedback networks in each amplifier stage. (The amplifier in all models whose model number ends in five, e.g.: 1015A, 1025A, etc., is tuned at 50 Hz). Transistor Q215 and photocell V202 ground the input signal from the summing junction when the overload control circuit is actuated. The control circuit pulls Q215 into conduction, causing the light in the photocell to reach peak intensity. The resistance of V202 drops toward zero, grounding the input signal.

3-27 DRIVER ASSEMBLY.

3-28 The amplified error signal is coupled to the driver assembly through capacitor C301. Transistors Q301 and Q302 form a tuned amplifier stage which provides equalization for reactive loads. Transistor Q303 is an untuned amplifier stage which drives a complementary emitter follower. The emitter follower is formed by transistors Q304 and Q305 and biased through resistors R314,R315,R317 and R318. The output of the emitter follower is capacitively coupled to the driver circuits.

3-29 The driver circuits separate the upper and lower signals for the upper and lower amplifiers, and provide error signal inputs to the power amplifiers.

3-30 The emitters of signal splitting transistors Q308 and Q309 are driven essentially in parallel through resistors R321 and R323. On positive half-cycles, PNP transistor Q309 conducts and Q308 is cut off. On negative half-cycles, NPN transistor Q309 conducts and Q308 is cut off. The drive signal to the lower power amplifier is referenced to -45 volts, through the collector of Q309. The drive signal to the upper power amplifier is referenced to the power amplifier output through the collector of Q308.

3-31 Transistor Q308 is collector-biased through diodes CR305, CR306 and CR307. The collector Q308 is biased at 15 volts more positive than the amplifier output through CR307. When the amplifier output becomes negative, and CR307 becomes reverse-biased, the collector of Q308 is clamped at +10 volts, through CR305.

3-32 The outputs of Q308 and Q309 are in phase. Transistor Q310 is a unity-gain phase inverter, necessary to obtain push-pull drive to the power amplifier. Q310 drives emitter follower Q311 (Q311 to Q314 in some models. Refer to the schematic diagram), which provides low source impedance to the base of Q501 in the upper power amplifier. Q309 drives emitter follower Q312 (Q312 to Q314 in some models) which provides low source impedance for the base of Q504 in the lower power amplifier.

3-33 Resistors R328,R330,R336 and R340 are current limiting resistors for circuit protection in case of a short circuit at the output.

3-34 Transistors Q306 and Q307 are control transistors which remove any input signal to the driver circuits when the overload control circuits are activated.

3-35 POWER AMPLIFIERS.

3-36 There are six variations in the power amplifier circuitry; therefore, they will be described as separate entities in each of the six basic models.

a. FR 1015A, 1016A. Two similar power amplifiers, mounted on identical heatsinks, provide output power-control voltage. The input plugs to the power amplifiers can be interchanged without damage to the circuits. The amplifiers, operated in push-pull configuration by the driver circuits, provide up to 30 volts RMS bucking voltage, to reduce voltage output, and up to 25 volts RMS boosting voltage, to raise voltage output.

In the upper amplifier, designated amplifier 1, emitter follower Q501 drives transistors Q502 and Q503 in parallel. Collector supply voltage Q502 and Q503 is provided by the +45 VDC supply. Resistor R501 is a current limiting resistor for short circuit protection. Diode CR501 provides protection from kickback surges in inductive loads. Thermocouple S501 activates the overload control circuits if the amplifier becomes

overheated.

In the lower amplifier, designated amplifier 2, the circuitry is similar in all details to the circuitry in amplifier 1. The emitters of transistors Q505 and Q506 are supplied by the -45VDC supply. -

b. FR1025A, 1026A. Two similar power amplifiers, mounted on identical heatsinks, provide output power control voltage. The input plugs to the power amplifiers can be interchanged without damage to the circuits. The amplifiers, operated in push-pull configuration by the driver circuits, provide up to 60 volts RMS bucking voltage to reduce voltage output, and up to 50 volts RMS boosting voltage, to raise voltage output.

In the upper amplifier, designated amplifier 1, emitter follower Q501 drives transistors Q504 and Q505 in parallel. Resistors R504 and R505 form a voltage divider across the amplifier output voltage. The base of transistor Q502 is connected to the midpoint of the voltage divider. The transistor, acting as an emitter follower, drives Q503 which is in series with Q504 and Q505. Half the output voltage is developed in Q503, and half is developed in Q504 and Q505. The arrangement reduces the heat dissipation requirements for the individual transistors, and permits better current regulation. Transistors Q504 and Q505 are insulated from the heatsink chassis. Resistor R501 is a current limiting resistor for short circuit protection. Diode CR502 provides protection from kickback surges in inductive loads. Thermostat S501 activates the overload control circuits if the amplifier becomes overheated.

In the lower amplifier, designated amplifier 2, the circuitry is similar in all details to the circuitry in amplifier 1. The heatsink chassis are similar and the input plugs may be interchanged without damage to the circuits.

c. FR2515A,2516A. Two similar power amplifiers, mounted on identical heatsinks, provide output power control voltage. The input plugs to the power amplifiers can be interchanged without damage to the circuits. The amplifiers, operated in push-pull configuration by the driver circuits, provide up to 30 volts RMS bucking voltage, to reduce voltage output, and up to 25 volts RMS boosting voltage, to raise voltage output.

In the upper amplifier, designated amplifier 1, emitter follower Q501 drives transistors Q502 through Q506 in parallel. Collector supplu voltage for Q502 through Q506 is provided by the +45 VDC supply. Resistor R501 is a current limiting resistor for short circuit protection. Diode CR501 provides protection from kickback surges in inductive loads. Thermocouple S501 activates the overload control circuits if the amplifier becomes overheated.

In the lower amplifier, designated amplifier 2, the circuitry is similar in all details to the circuitry in amplifier 1. The emitters of transistors Q509 through Q512 are supplied by the -45 VDC supply.

d. FR2525A, 2526A. Two similar power amplifiers, mounted on identical heatsinks, provide output power control voltage. The input plugs to the power amplifiers can be interchanged without damage to the circuits. The amplifiers, operated in push-pull configuration by the driver circuits, provide up to 60 volts RMS bucking voltage, to reduce voltage output, and up to 50 volts RMS boosting voltage, to raise voltage output.

In the upper amplifier, designated amplifier 1, emitter follower Q501 drives transistors Q504, Q506, and Q508 in parallel. Resistors R503 and R504 form a voltage divider across the amplifier output voltage. The base of transistor Q502 is connected to the midpoint of the voltage divider. This transistor, acting as an emitter follower, drives Q503, Q505 and Q507 which are in series with Q504, Q506 and Q508. Resistor R501 is a current limiting resistor for short circuit protection. Diode CR502 provides protection from kickback surges in inductive loads. Thermostat S501 activates the overload control circuits if the amplifier becomes overheated.

In the lower amplifier, designated amplifier 2, the circuitry is similar in all details to the circuitry in amplifier 1.

e. FR5015A,5016A. Two similar power amplifiers, mounted on four heatsinks, provide output power control voltage. The input plugs to the power amplifiers can be interchanged without damage to the circuits. The amplifiers, operated in push-pull configuration by the driver circuits, provide up to 30 volts RMS bucking voltage, to reduce

voltage output, and up to 25 volts RMS boosting voltage, to raise voltage output.

In amplifier No. 1, comprised of heat sinks No. 1 and 2, emitter follower Q501 drives Q502 through Q506, and Q511 drives Q512 through Q516. Likewise, on amplifier No. 2, comprised of heat sinks No. 3 and 4, Q522 through Q526 are driven by Q521, and Q532 through Q536 are driven by Q531.

f. FR5025A,5026A. The power amplifier consists of upper and lower amplifier sections connected in a series push-pull configuration to provide up to 60 volts RMS busking voltage, to reduce voltage output, and up to 50 volts RMS boosting voltage, to raise voltage output.

In the upper amplifier, emitter follower Q511 drives transistors Q512 through Q516 in parallel. Resistors R15 and R16 form a voltage divider across the amplifier output voltage. The base of transistor Q501 is connected to the midpoint of the voltage divider. This transistor, acting as an emitter follower, drives Q502 through Q506 in parallel. These transistors are in series with Q512 through Q516 so that the amplifier output voltage is divided between them. Resistor R511 is a current-limiting resistor for short circuit protection. Diodes CE501 and CR511 provide protection from kickback surges in inductive loads. Thermostat S511 activates the overload control circuits if the amplifier becomes overheated.

In the lower amplifier, the circuitry is similar in all details to the circuitry in the upper amplifier. The two 12-pin heat sink connectors may be interchanged with one another, as may the two 8-pin connectors, without affecting power amplifier operation.

3-37 POWER SUPPLY and CONTROL ASSEMBLY.

3-38 Transistors Q101,Q102, and Q103 form a series regulator for the +10 VDC supply. The positive output is compared with a zener reference in Q103. The error signal is amplified in Q102, which provides base drive current for series regulator Q101. Transistors Q104,Q105, and Q106 form a series regulator for the -10 VDC supply. The negative output is compared to the +10 VDC output.

3-39 The overload control circuits consists of a monostable, Q107 and Q108, and a regenerative time delay amplifier, Q109 and Q110.

3-40 The regulated output is sampled by current sampling resistors R8 and R9. The sample is applied to an averaging rectifier, diode CR102, resistors R113 and R115, and capacitor C103, and a peak rectifier, CR104, CR105, CR106 and CR107. An average load in excess of nine amperes, or any peak load in excess of thirty amperes, triggers the monostable.

3-41 The monostable also is triggered by an over-voltage condition at the power input. An input voltage greater or less than the selected input range causes an excessive compensating voltage at the amplifier output (TP 2). If the amplifier output exceeds 51 volts positive or negative, the monostable is tripped. An excessive positive voltage is passed through diode CR113, Zener diode CR116, and diode CR115 to the base of Q108, cutting the transistor off. An excessive negative voltage is passed through diode CR112, Zener diode CR116, and diode CR114 to the base of Q107, cutting the transistor off. Zener diode CR116 has a nominal break-down of 51 volts.

3-42 Capacitor C104 and resistor R118 provide 4-second timing for the monostable. When power is first applied to the line conditioner, the monostable assumes the triggered state. The circuit remains in the triggered state until capacitor C104 becomes charged, a period of approximately four seconds. During the time th- monostable is in the triggered state the red overload indicator on the front panel is lighted.

3-43 The regenerative time delay amplifier prevents re-triggering the overload monostable during the charging time of C104. The amplifier overload signal is applied to the control line through emitter follower Q111, and to the SCR trigger circuit Q114 and Q115. Transistors Q112 and Q113 provide current gain to to drive the overload indicator DS2.

3-44 SILICON CONTROLLED RECTIFIER ASSEMBLY.

3-45 The SCR assembly is mounted on a separate heatsink. Diodes CR7,CR8,CR9

and CR10 form a diode bridge which allows overload current to flow in either direction, yet always to flow through the SCR in the forward direction. The output of the SCR is applied to pin 14 of the power transformer secondary, reducing the transformer output in overload conditions and bypassing overload current around the power amplifier. Diode CR6 provides bias for the SCR gate junction.

3-46 LOW VOLTAGE POWER SUPPLIES.

3-47 Transformer T1 secondary winding between pin 9 and pin 13 provides power to the +45 VDC and -45 VDC power supply. Diodes CR1,CR2,CR3 and CR4 are mounted on a separate heatsink directly behind the fan. The rectifier bridge output is filtered by capacitors C4 and C5 and resistors R5 and R6, mounted on the motherboard.

3-48 Fuse F1 is located in the primary winding circuit of transformer T2, which is driven by the secondary winding of transformer T1. Transformer T2 has three secondary windings, which drive three low voltage power supplies. The rectifier bridges and the filter capacitors for the power supplies are mounted on the motherboard. Winding 3,4 and 5 supplies positive and negative 15 VDC to drive the positive and negative 10 VDC regulators.

3-49 Winding 6, 7 and 8 drives a floating +15 VDC and -15 VDC power supply which provides base bias for the lower power amplifier emitter follower input. The center tap is reference to -45 volts. One output of the rectifier bridge is -45 volts +15 volts (-30 volts) and the other output is -45 volts -15 volts (-60 volts). In models with 190-270 volts input, the output of the rectifier bridge is -90 volts +15 volts (-75 volts) and the other output is -90 volts -15 volts (-105 volts).

3-50 Winding 9, 10 and 11 drives a floating +15 VDC and -15 VDC power supply which provides base bias for the upper power amplifier emitter follower input. The center tap at pin 10 is referenced to the amplifier output potential. One output of the rectifier bridge is at a potential 15 volts higher than the amplifier output potential. The other output from the rectifier bridge is at a potential 15 volts lower than the amplifier output potential.

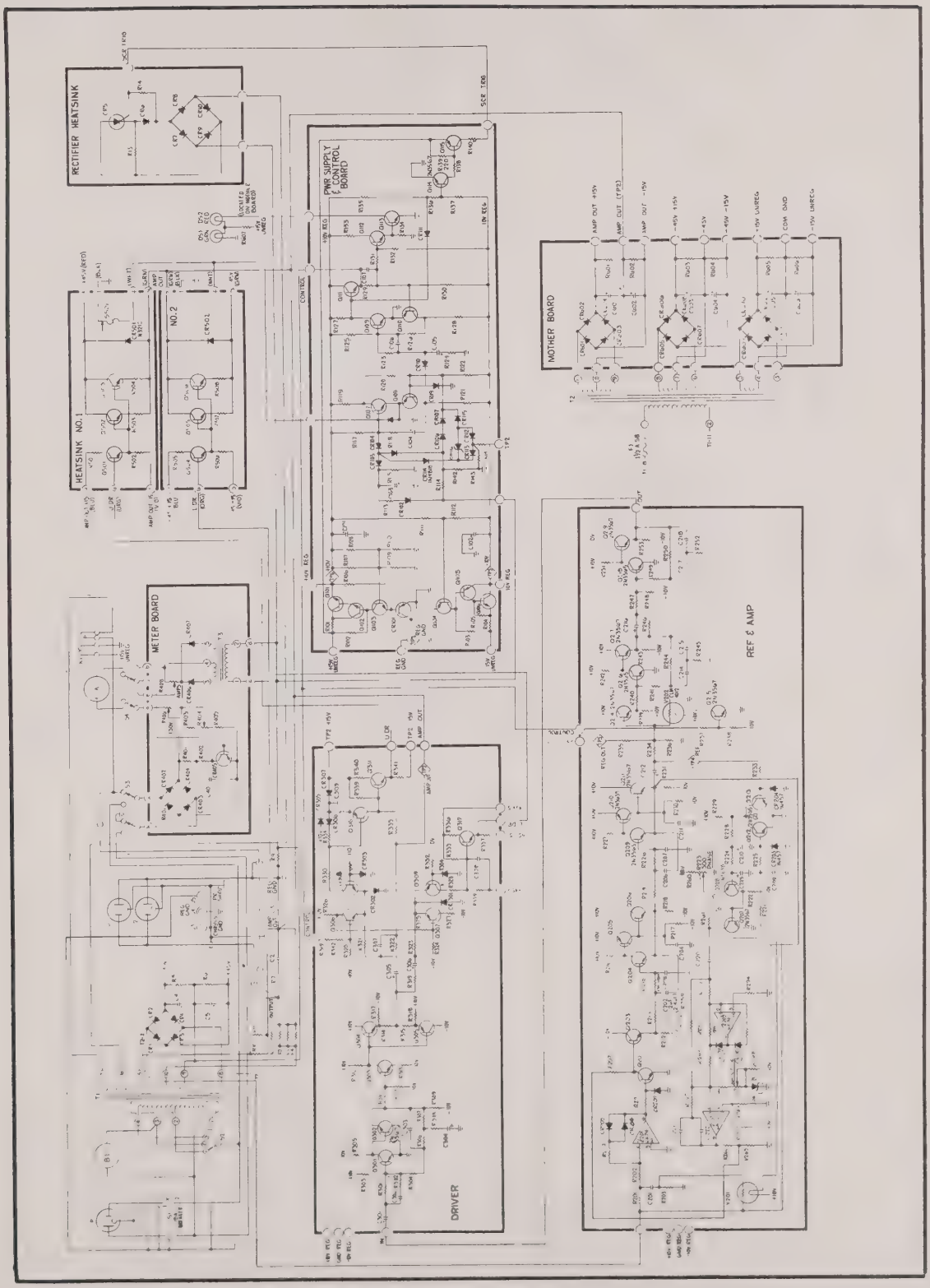


Figure 3-2. Typical Overall Schematic Diagram (Models 1015A/1016A).

SECTION IV
MAINTENANCE

4-1 SERVICE INFORMATION.

4-2 Questions concerning the operation, repair, or servicing of FR instruments should be directed to the nearest Sorensen representative or to the Service Department, Sorensen Company, 676 Island Pond Road, Manchester, New Hampshire, 03103. INCLUDE THE MODEL and SERIAL NUMBERS is any correspondence. If it is necessary to return the equipment to the factory for repair, contact the Service Department for authorization to make shipment.

DO NOT RETURN THE UNIT FOR REPAIR WITHOUT AUTHORIZATION.

4-3 TEST POINTS.

4-4 Circuit operation for each major assembly can be tested through the convenient test points provided at the top of each plug-in circuit board. Test points are shown in Figure 4-1. The correct voltage indication at each test point is given in the following list:

TP1 - Brown - Regulator ground - Common for all measurements.

TP2 - Red - Amp output - varies widely.

TP3 - Orange - Regulated output - 115V lo-distortion sine wave

CAUTION

In the 190-270 VAC input models, TP3 is located in the middle of the summing resistor R235 and R610. Connecting an oscilloscope probe to the test point causes an increase in the line conditioner output voltage.

TP4 - Yellow - Reference - Approximately 2.8V (5.6V in the 190-270 VDC models) P-P lo-distortion sine wave.

TP5 - Green - -10±.5 VDC.

TP6 - Blue - +10±.5 VDC.

TROUBLE SHOOTING CHART

CIRCUIT BREAKER TRIPS:	The line conditioner may be overloaded or the output terminals short circuited. Remove the load. If the circuit breaker still trips, a malfunction in the high power circuitry is likely. Pull out both amplifier plugs shown in Figure 4-1. If the circuit breaker holds, there is probably a short-circuited power transistor or diode on one of the power amplifier heatsinks. If the circuit breaker still trips, a failure in one of the low voltage power supplies is likely.
POOR REGULATION:	Rear panel tap switch may not be in correct position. Input voltage or input frequency may be outside acceptable limits. Reference phase or output amplitude potentiometers may be improperly adjusted.
RED LIGHT COMES ON OR CYCLES ON AND OFF:	The red light normally stays on for four seconds after power is applied. It will also come on temporarily for loads drawing heavy starting or inrush currents. The red light also indicates excessive peak or average load current, or overheating due to excessive environmental temperature or obstructed air flow.
NO OUTPUT VOLTAGE BY FAN RUNS:	Blown low voltage fuse. The fuse is shown in Figure 4-1. Replace with 1-1/2 a slow-blow fuse. Blown fuse indicates component failures in the low voltage power supplies.

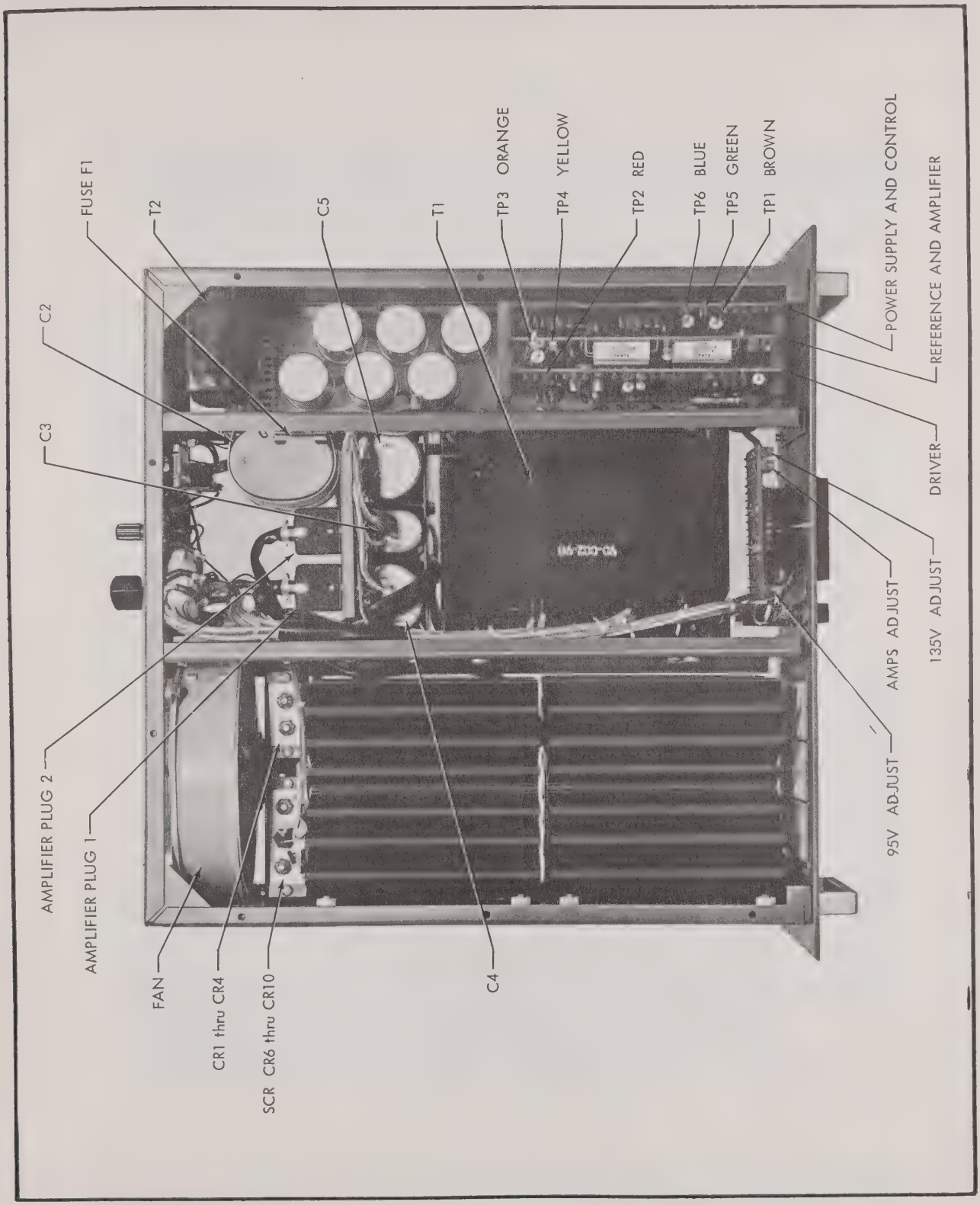


Figure 4-1. FR 1000 Series Chassis Showing Component Locations.

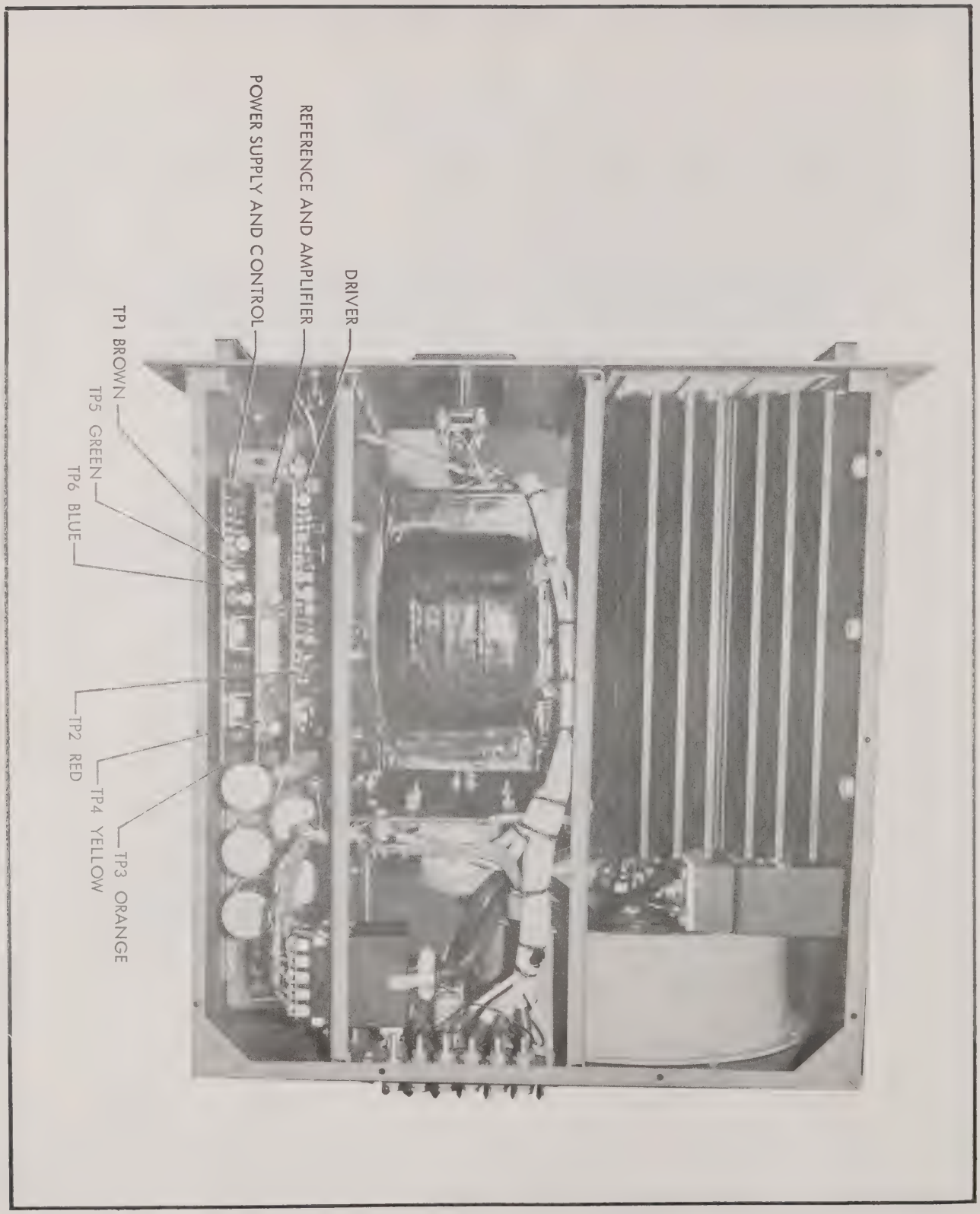


Figure 4-2. FR 2500 Series Chassis Showing Component Locations.

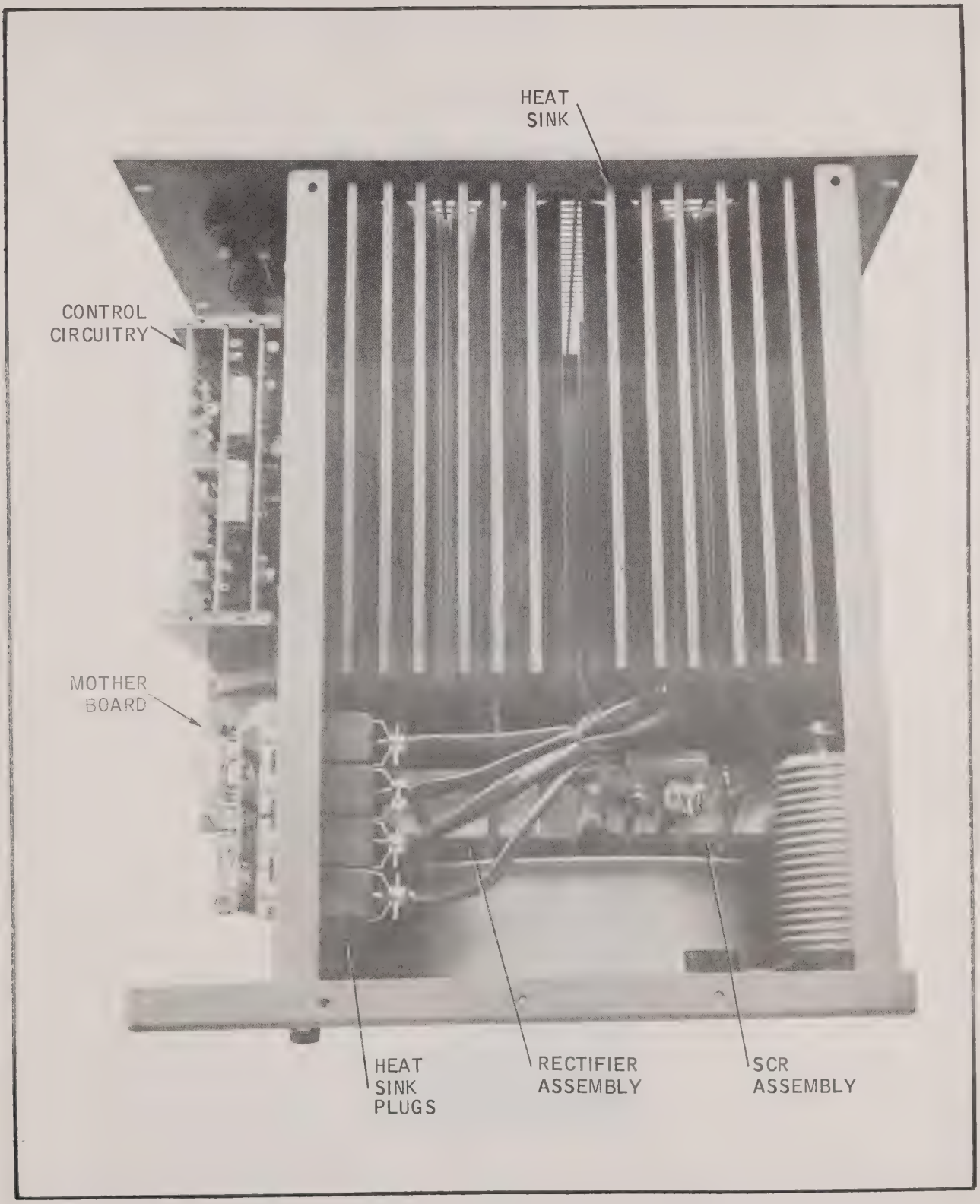


Figure 4-3. FR 5000 Series Chassis Showing Component Locations.

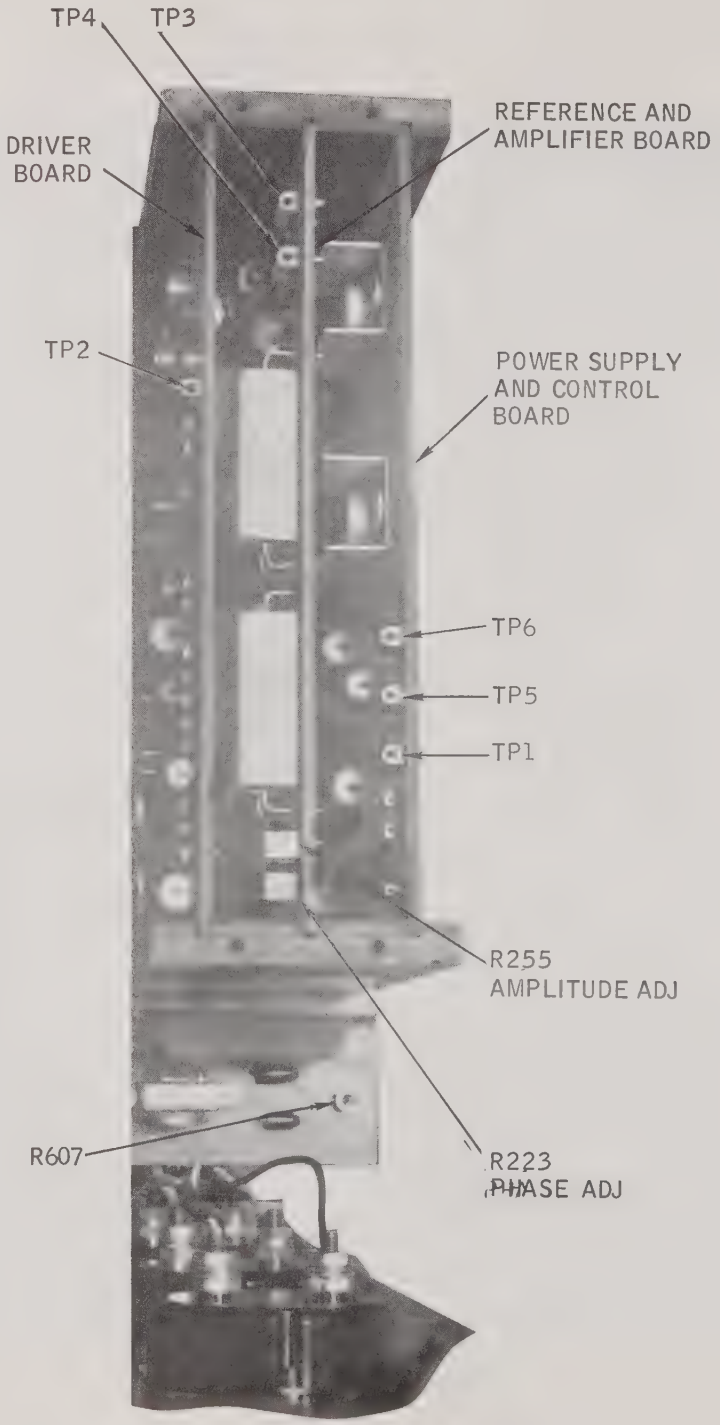


Figure 4-4. Test and Adjustment Points.

SECTION V
REPLACEMENT PARTS LIST

5-1 INTRODUCTION.

5-2 This section provides a set of coded replacement parts lists keyed to the individual schematic diagrams of the component boards, some of which are common to all units, and the chassis, motherboard and Rectifier Heatsink assemblies. Where component boards differ in the various units, separate diagrams and lists are included and are identified with the associated units.

5-3 MODEL CODING.

5-4 To simplify the listing of parts for six basic models, a code system of numbers has been devised. When no model code is used, it indicates that the component is used in all models. The cross-reference list of codes and Models follows:

CODE	MODEL
1	1015A/1016A
2	1025A/1026A
3	2515A/2516A
4	2525A/2526A
5	5015A/5016A
6	5025A/5026A

5-5 MANUFACTURING CODING.

5-6 The column headed MANUFACTURER-PART NUMBER/CODE contains a listing of manufacturers part numbers and letter designators. The letter designators, when applied to the tabulation that follows, will give the manufacturer from whom a particular item may be purchased. The item may also be ordered through Sorensen. See ORDERING PARTS.

AX	AEROVOX
AO	AMELCO
AN	AMMON
AR	ARCO
BR	BOURNS
CL	CLAIREX
CO	CORNING
DA	DALE
EL	ELGAR
EP	ELPAC
ER	ERIE
FC	FAIRCHILD
GE	GENERAL ELECTRIC
GR	GRAYHILL
HM	HEINEMAN
HP	HELIPOT
IR	INT. RECTIFIER CORP.
LF	LITTLEFUSE
MA	MAGNECRAFT
MY	MALLORY
MO	MOTOROLA
OM	OHMITE
RCA	RADIO CORP. OF AMERICA
RN	ROTRON
SA	SANGAMO
SM	SEMTECH
SP	SPRAGUE
SD	STABLE DYNAMICS
STA	STACKPOLE
SO	STEMCO

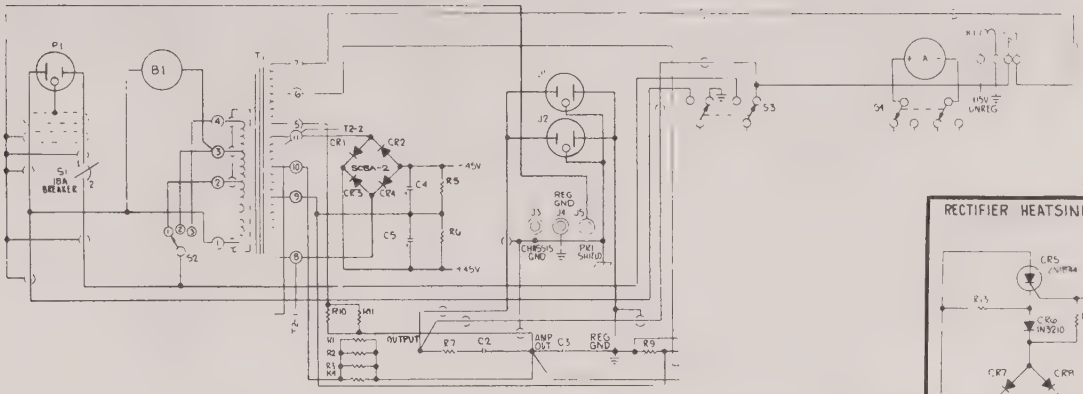
SV	SYLVANIA
SW	SWITCHCRAFT
TI	TEXAS INSTRUMENT
WL	WARD LEONARD
WH	WESTINGHOUSE

5-7 ORDERING PARTS.

5-8 When ordering parts, include the manufacturer's name and part number, a complete description of the item, and the unit model number.

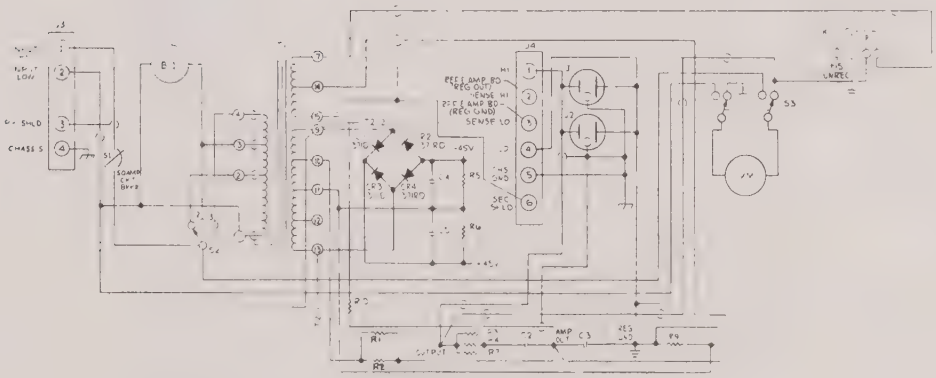
Address orders to:

Sorensen Company
676 Island Pond Road
Manchester, New Hampshire
03103

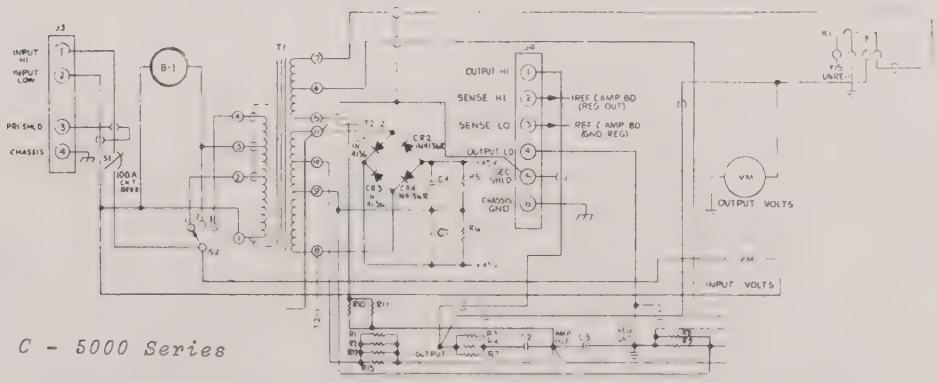


A - 1000 Series

D - ALL MODELS



B - 2500 Series



C - 5000 Series

SCR Heatsink and 90 Volt Power Supply and Chassis Mounted Components.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
RESISTOR									
R13		A	L	L			WW, 100, 50W		DA
R14	M	O	D	E	L	S	CARBON, 47, 1/2W, 5%		STA
SEMICONDUCTOR									
CR1,CR3		A	L	L			RECTIFIER	1N1187	WH
CR2,CR4							RECTIFIER	1N1187R	WH
CR5	M	O	D	E	L	S	SILICON CONTROLLED RECTIFIER	213B	WH
CR6,CR9,CR10							RECTIFIER	1N1186	WH
CR7,CR8							RECTIFIER	1N1186R	WH
B1		A	L	L			FAN, 270 CFM	103	RN
F1		A	L	L			FUSE, 1-1/2A	31301.5	LF
T1		A	L	L			TRANSFORMER	90-019-90	EL
T2		A	L	L			TRANSFORMER	90-003-90	EL
S1		A	L	L			CIRCUITBREAKER, 10A	JA1-A3-250-10.3A	HM
S2		A	L	L			SWITCH, 20A	19001-3	GR
S3	x	x	x	x			SWITCH	1006	SW
S4	x	x					SWITCH	1006	SW
DS1,DS2		A	L	L			BULB	330	GE

Table 5-1. SCR Heatsink and 90 volt Power Supply and chassis mounted components.

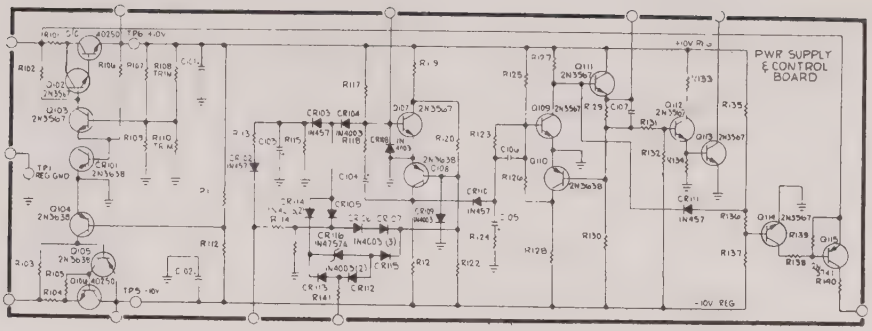


Table 5-2. Power Supply and Control Assembly - Models 1, 2, 3, 5.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	CODE
CAPACITOR									
C101,C102	x	x	x		x		ELECTROLYTIC, 100 ufd, 15V	TE 1162	SP
C103	x	x	x		x		ELECTROLYTIC, 100 ufd, 6V	TE 1102	SP
C104	x	x	x		x		ELECTROLYTIC, 200 ufd, 12V	TE 1137	SP
C105	x	x	x		x		ELECTROLYTIC, 50 ufd, 15V	TE 1160	SP
C106,C107	x	x	x		x		DISC, .001 ufd, 1000V	801Z5V102P	ER
RESISTOR									
R101,R104	x	x	x		x		CARBON, 10, 2W, 5%		STA
R102,R103, R118,R120, R127,R137	x	x	x		x		CARBON, 3.3K, 1/2W, 5%		STA
R105	x	x	x		x		CARBON, 220, 1/2W, 5%		STA
R106	x	x	x		x		CARBON, 620, 1/2W, 5%		STA
R107	x	x	x		x		TIN OXIDE, 1330, 1%	RN60B1331F	CO
R108,R110							SEL VAL, may be omitted on some units		
R109	x	x	x		x		TIN OXIDE, 2490, 1/8W, 1%	RN60B2491F	CO
R111	x	x	x		x		TIN OXIDE, 5230, 1/8W, 1%	RN60B5231F,	CO
R112	x	x	x		x		TIN OXIDE, 4750, 1/8W, 1%	RN60B4751F	CO
R113	x	x	x		x		CARBON, 150, 1/2W, 5%		STA
R114	x	x	x		x		CARBON, 82, 1/2W, 5%		STA
R115,R131	x	x	x		x		CARBON, 4.7K, 1/2W, 5%		STA
R116	x	x	x		x		CARBON, 10, 1/2W, 5%		STA
R117,R122, R123,R132	x	x	x		x		CARBON, 10K, 1/2W, 5%		STA
R119,R121, R124,R128, R133,R134, R135,R136	x	x	x		x		CARBON, 1K, 1/2W, 5%		STA
R125	x	x	x		x		CARBON, 18K, 1/2W, 5%		STA
R126	x	x	x		x		CARBON, 33K, 1/2W, 5%		STA
R129	x	x	x		x		CARBON, 8.2K, 1/2W, 5%		STA
R130	x	x	x		x		CARBON, 15K, 1/2W, 5%		STA
R138	x	x	x		x		CARBON, 470, 1/2W, 5%		STA
R139	x	x	x		x		CARBON, 220, 1/2W, 5%		STA
R140	x	x	x		x		CARBON, 47, 2W, 5%		STA
R141	x	x	x		x		CARBON, 1.5K, 1/2W, 5%		STA

REFERENCE DESIGNATION	MODEL CODE						DESCRIPTION	MANUFACTURER	
	1	2	3	4	5	6		PART NUMBER	CODE
SEMICONDUCTOR									
CR101	x	x	x		x		ZENER, 6.2V	2N3638	FC
CR116	x	x	x		x		ZENER, 51V	1N4757A	MO
CR102,CR103, CR110,CR111	x	x	x		x		DIODE, 70V, 100 ma	1N457	SV
CR104 thru CR109	x	x	x		x		RECTIFIER, 200V, 1A	1N4818	WH
TRANSISTOR									
Q101,Q106	x	x	x		x			40250 V1	RCA
Q102,Q103, Q107,Q109, Q111 thru Q114	x	x	x		x			2N3567	FC
Q104,Q105, Q108,Q110	x	x	x		x			2N3638	FC
Q115	x	x	x		x			2N4356	FC

Table 5-2. Power Supply and Control Assembly - Models 1, 2, 3, 5 (continued).

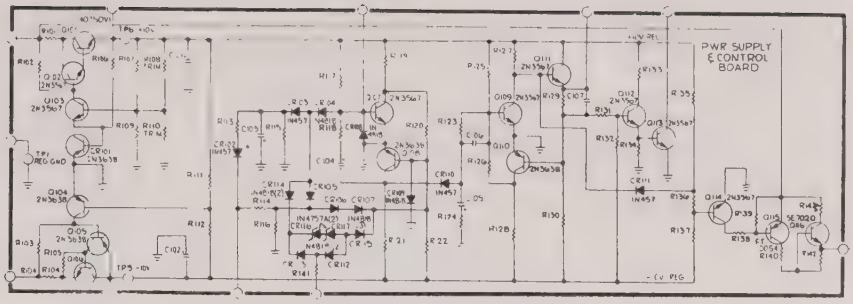


Table 5-3. Power Supply and Control Assembly - Models 4, 6.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
CAPACITOR									
C101,C102				x		x	ELECTROLYTIC, 100 ufd, 15V	TE 1162	SP
C103				x		x	ELECTROLYTIC, 100 ufd, 6V	TE 1102	SP
C104				x		x	ELECTROLYTIC, 200 ufd, 12V	TE 1137	SP
C105				x		x	ELECTROLYTIC, 50 ufd, 15V	TE 1160	SP
C106,C107				x		x	DISC, .001 ufd, 1000V	801Z5V102P	ER
RESISTOR									
R101,R104				x		x	CARBON, 10, 2W, 5%		STA
R102,R103, R118,R120, R127,R137				x		x	CARBON, 3.3K, 1/2W, 5%		STA
R105,R139				x		x	CARBON, 220, 1/2W, 5%		STA
R106				x		x	CARBON, 620, 1/2W, 5%		STA
R107				x		x	TIN OXIDE, 1330, 1%	RN60B1331F	CO
R108,R110							SEL VAL, may be omitted on some units		
R109				x		x	TIN OXIDE, 2490, 1/8W, 1%	RN60B2491F	CO
R111				x		x	TIN OXIDE, 5230, 1/8W, 1%	RN60B5231F	CO
R112				x		x	TIN OXIDE, 4750, 1/8W, 1%	RN60B4751F	CO
R113				x		x	CARBON, 150, 1/2W, 5%		STA
R114				x		x	CARBON, 82, 1/2W, 5%		STA
R115,R131				x		x	CARBON, 4.7K, 1/2W, 5%		STA
R116				x		x	CARBON, 10, 1/2W, 5%		STA
R117,R122, R123,R132				x		x	CARBON, 10K, 1/2W, 5%		STA
R119,R121, R124,R128, R133,R134, R135,R136				x		x	CARBON, 1K, 1/2W, 5%		STA
R125				x		x	CARBON, 18K, 1/2W, 5%		STA
R126				x		x	CARBON, 33K, 1/2W, 5%		STA
R129				x		x	CARBON, 8.2K, 1/2W, 5%		STA
R130				x		x	CARBON, 15K, 1/2W, 5%		STA
R138,R140, R142				x		x	CARBON, 470, 1/2W, 5%		STA
R139				x		x	CARBON, 220, 1/2W, 5%		STA
R141				x		x	CARBON, 1.5K, 1/2W, 5%		STA
R143				x		x	WW, 25, 5W, 5%	AS-5	IR

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
SEMICONDUCTOR									
CR101				x		x	ZENER, 6.2V	2N3638	FC
CR116,CR117				x		x	ZENER, 51V	1N4757A	MO
CR102,CR103, CR110,CR111				x		x	DIODE, 70V, 100 ma	1N457	SV
CR104 thru CR109,CR112 thru CR115				x		x	RECTIFIER, 200V, 1A	1N4818	WH
TRANSISTOR									
Q101,Q106				x		x		40250 V1	RCA
Q102,Q103, Q107,Q109, Q111 thru Q114				x		x		2N3567	FC
Q104,Q105, Q108,Q110				x		x		2N3638	FC
Q115				x		x		FT0054	FC
Q116				x		x		SE7020	FC

Table 5-3. Power Supply and Control Assembly - Models 4, 6 (continued).

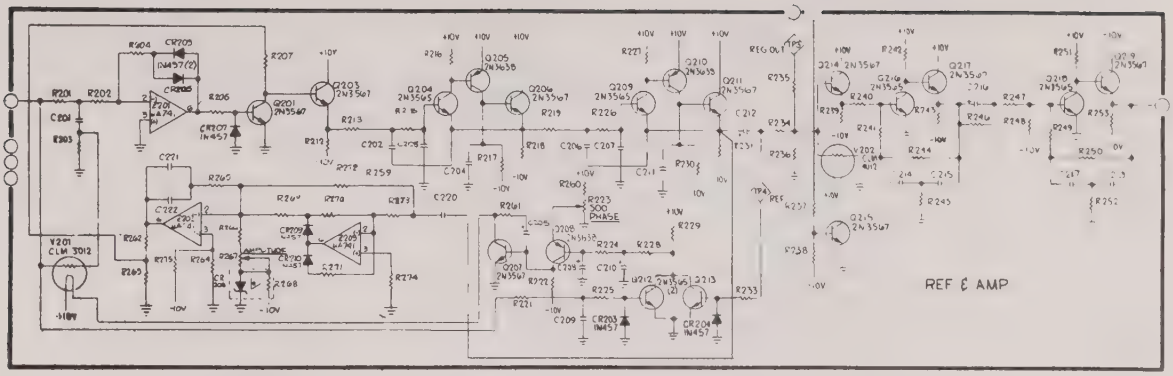


Table 5-4. Reference and Amplifier Assembly - All Models.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
CAPACITORS									
C202,C206, C220							POLY CARB, 2 ufd, 1%	B1A205F	EP
C203							POLY CARB, .0082 ufd, 1%	B1A822F	EP
C204,C211		A	L	L			CERAM DISC, .01 ufd	811Z5V103P	ER
C205,C212							ELECTROLYTIC, 200 ufd, 12V	TE 1137	SP
C207	M	O	D	E	L	S	POLY CARB, .024 ufd, 100V, 1%	B1A243F	EP
C208, C210							ELECTROLYTIC, 5 ufd, 12V	TE 1127	SP
C209,C201							MYLAR, .47 ufd, 200V, 5%	ZD2A474J	EP
C214,C215, C217,C218, C221,C222							MYLAR, 2 ufd, 200V, 1%	ZD2A205F	EP
RESISTORS									
R268								90-097-90	SD
R243,R253, R261,R265							CARBON, 1.5K, 1/2W, 5%		STA
R205							CARBON, 3.9K, 1/2W, 5%		STA
R216,R217, R221,R225, R227,R229, R230,R241, R249	M	A O	L D	L E	L	S	CARBON, 10K, 1/2W, 5%		STA
R207							CARBON, 470, 1/2W, 5%		STA
R246							CARBON, 100K, 1/2W, 5%		STA
R275							CARBON, 1.5M, 1/2W, 5%		STA
R231							CARBON, 1K, 1/2W, 5%		STA
R212,R218, R204,R224, R228,R233, R236,R239, R242,R251, R264,R274							CARBON, 4.7K, 1/2W, 5%		STA
R213,R215							TIN OXIDE, 18.2K, 1/8W, 1%	RN60D 1822F	CO
R219,R226							TIN OXIDE, 13.3K, 1/8W, 1%	RN60D 1332F	CO
R201,R202, R222,R238							CARBON, 33K, 1/2W, 5%		STA

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	7	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
R223							TRIMPOT, 500	275-1-501	BR
R262							CARBON, 22K, 1/2W, 5%		STA
R234							TIN OXIDE, 3.92K, 1/8W, 1%	RN60D 3921F	CO
R235							TIN OXIDE, 150K, 1/4W, 1%	RN65D 1503F	CO
R237,R247, R203							CARBON, 3.3K, 1/2W, 5%		STA
R240							CARBON, 6.8K, 1/2W, 5%		STA
R244,R250							TIN OXIDE, 9.76K, 1/8W, 1%	RN60D 9761F	CO
R245,R252							TIN OXIDE, 178, 1/8W, 1%	RN60D 1780F	CO
R248							CARBON, 470K, 1/2W, 5%		STA
R267							TRIMPOT, 5K,	275-1-502	BR
R266,R270, R271							TIN OXIDE, 20K, 1/8W, 1%	RN60C 6341F	CO
R260							TIN OXIDE, 2.21K, 1/8W, 1%	RN60C 2211F	CO
R269,R272, R273							TIN OXIDE, 10K, 1/8W, 1%	RN60C 1002F	CO
SEMICONDUCTORS									
CR203,CR204, CR205,CR210		A	L	L			DIODE, 70V, 100 ma	1N457	SV
CR206,CR207, CR209	M	O	D	E	L	S		1N821	IR
CR208(R268)								90-097-90	SD
TRANSISTORS									
Q201,Q203, Q206,Q207, Q211,Q214, Q215,Q217, Q219	M	A O	L D	L E	L	S		2N3567	FC
Q204,Q209, Q212,Q213, Q216,Q218								2N3565	FC
Q205,Q208, Q210								2N3638	FC
PHOTO MODULATOR									
V201							Clairex	CLM 3012	CL
V202							Clairex	CLM 4012	CL
INTEGRATED CIRCUITS									
Z201,Z202, Z203							OP. AMP.	UA741	FC

Table 5-4. Reference and Amplifier Assembly - All Models (continued).

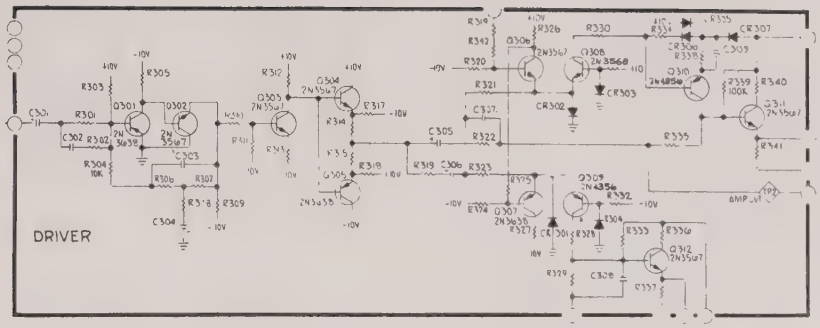


Table 5-5. Driver Assembly - Models 1, 2, 4.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	CODE
CAPACITOR									
C301,C306	x	x		x			ELECTROLYTIC, 200 ufd, 12V	TE 1137	SP
C302	x	x		x			MYLAR, .1 ufd, 200V	V161	AX
C303	x	x		x			MYLAR, .01 ufd, 200V	V161	AX
C304	x	x		x			ELECTROLYTIC, 50 ufd, 6V	TE 1100	SP
C305	x	x		x			ELECTROLYTIC, 20 ufd, 6V	TE 1090	SP
C307	x	x		x			DIP MICA, .001 ufd, 500V	DM 15-102J	AR
C308	x	x		x			DIP MICA, 220 pfd, 500V	DM 15-221J	AR
C309	x	x		x			DIP MICA, 470 pfd, 500V	DM 15-471J	AR
RESISTOR									
R301,R316, R328 thru R330,R335	x	x		x			CARBON, 2.2K, 1/2W, 5%		STA
R302	x	x		x			CARBON, 1.5K, 1/2W, 5%		STA
R303	x	x		x			CARBON, 51K, 1/2W, 5%		STA
R304,R320, R324	x	x		x			CARBON, 10K, 1/2W, 5%		STA
R305 thru R307,R317, R318,R325, R331,R332	x	x		x			CARBON, 4.7K, 1/2W, 5%		STA
R308,R309, R326,R327	x	x		x			CARBON, 470, 1/2W, 5%		STA
R310,R311	x	x		x			CARBON, 1.2K, 1/2W, 5%		STA
R312,R322, R337,R341	x	x		x			CARBON, 3.3K, 1/2W, 5%		STA
R313,R319, R321,R323, R334,R338, R342	x	x		x			CARBON, 1K , 1/2W, 5%		STA
R314,R315	x	x		x			CARBON, 100, 1/2W, 5%		STA
R333,R339	x	x		x			CARBON, 100K, 1/2W, 5%		STA
R336,R340	x	x		x			CARBON, 220, 1/2W, 5%		STA
SEMICONDUCTOR									
CR301 thru CR307	x	x		x			DIODE, 70V, 100 ma	1N457	SV

REFERENCE DESIGNATION	MODEL CODE						DESCRIPTION	MANUFACTURER	
	1	2	3	4	5	6		PART NUMBER	CODE
TRANSISTOR									
Q301,Q305, Q307	x	x		x				2N3638	FC
Q302 thru Q304,Q306, Q311,Q312	x	x		x				2N3567	FC
Q308	x	x		x				2N3568	FC
Q309,Q310	x	x		x				2N4356	FC

Table 5-5. Driver Assembly - Models 1, 2, 4 (continued).

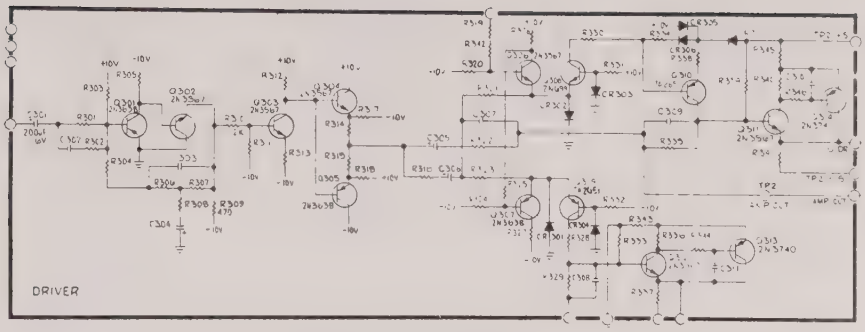


Table 5-6. Driver Assembly - Models 3, 5, 6.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
CAPACITOR									
C301,C306			x		x	x	ELECTROLYTIC, 200 ufd, 12V	TE 1137	SP
C302			x		x	x	MYLAR, .1 ufd, 200V	V161	AX
C303			x		x	x	MYLAR, .01 ufd, 200V	V161	AX
C304			x		x	x	ELECTROLYTIC, 50 ufd, 6V	TE 1100	SP
C305			x		x	x	ELECTROLYTIC, 20 ufd, 6V	TE 1090	SP
C307			x		x	x	DIP MICA, .001 ufd, 500V	DM 15-102J	AR
C308,C309			x		x	x	DIP MICA, 1500 pfd, 500V	DM 15-152J	AR
C310,C311			x		x	x	DIP MICA, .005 ufd, 500V	DM 15-502J	AR
RESISTOR									
R301,R316, R328 thru R330,R335			x		x	x	CARBON, 2.2K, 1/2W, 5%		STA
R302			x		x	x	CARBON, 1.5K, 1/2W, 5%		STA
R303			x		x	x	CARBON, 51K, 1/2W, 5%		STA
R304,R320, R324			x		x	x	CARBON, 10K, 1/2W, 5%		STA
R305 thru R307,R317, R318,R325, R331,R332			x		x	x	CARBON, 4.7K, 1/2W, 5%		STA
R308,R309, R326,R327			x		x	x	CARBON, 470, 1/2W, 5%		STA
R310,R311			x		x	x	CARBON, 1.2K, 1/2W, 5%		STA
R312,R322, R337,R341			x		x	x	CARBON, 3.3K, 1/2W, 5%		STA
R313,R319, R321,R323, R334,R338, R342			x		x	x	CARBON, 1K, 1/2W, 5%		STA
R314,R315			x		x	x	CARBON, 100, 1/2W, 5%		STA
R333,R339			x		x	x	CARBON, 100K, 1/2W, 5%		STA
R336,R340			x		x	x	CARBON, 220, 1/2W, 5%		STA
SEMICONDUCTOR									
CR301 thru CR307			x		x	x	DIODE, 70V, 100 ma	1N457	SV

REFERENCE DESIGNATION	MODEL CODE						DESCRIPTION	MANUFACTURER	
	1	2	3	4	5	6		PART NUMBER	CODE
TRANSISTOR									
Q301,Q305, Q307			x		x	x		2N3638	FC
Q302 thru Q304,Q306, Q311,Q312			x		x	x		2N3567	FC
Q308			x		x	x		2N699	TI
Q309,Q310			x		x	x		TA2651	RCA
Q313,Q314			x		x	x		2N3740	MO

Table 5-6. Driver Assembly - Models 3, 5, 6 (continued).

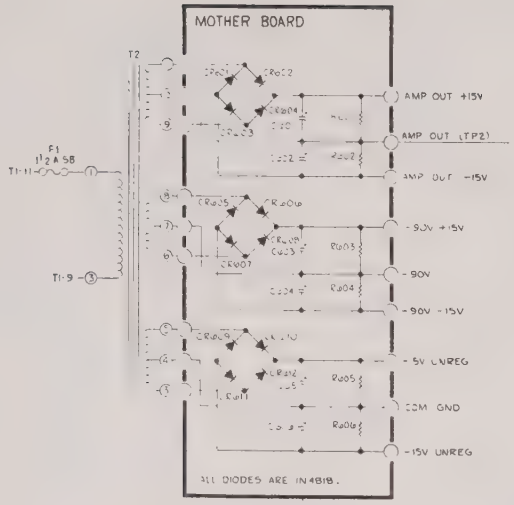


Table 5-7. Motherboard Assembly - Models 1, 2, 3, 4.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
CAPACITOR									
C2	x	x	x	x			OILED PAPER, 20 ufd, 230V	OP2036	MY
C3	x	x	x	x			OILED PAPER, 7.5 ufd, 230V	OP7X36	MY
C4,C5	x	x	x	x			ELECTROLYTIC, 5900 ufd, 75V	36D592F-075BC.2A	SP
C601 thru C606	x	x	x	x			ELECTROLYTIC, 3000 ufd, 25V	PWP 201.3A	MY
RESISTOR									
R1 thru R4	x	x	x	x			WW, 20, 50W, 5%	RH50	DA
R5,R6	x	x	x	x			CARBON, 10K, 2W, 5%		STA
R7	x	x	x	x			WW, 2.5, 10W, 5%	AS-10	IR
R9	x	x	x	x			WW, .1, 10W, 5%	CW10	DA
R10,R11	x	x	x	x			WW, 1.5, 50W, 5%	RH50	DA
R601 thru R606	x	x	x	x			CARBON, 4.7K, 1/2W, 5%		STA
R607	x	x	x	x			CARBON, 43, 1/2W, 5%		STA
SEMICONDUCTOR									
CR601 thru CR612	x	x	x	x			RECTIFIER, 200V, 1A	1N4818	WH

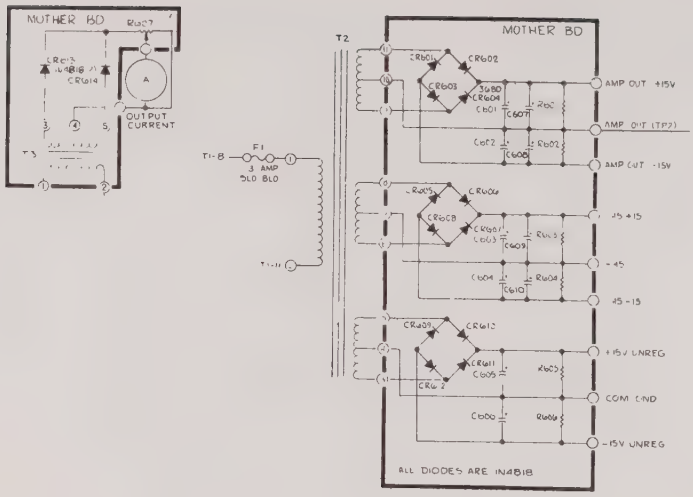


Table 5-8. Motherboard Assembly - Models 5, 6.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
CAPACITOR									
C601 thru C610					x	x	ELECTROLYTIC, 3000 ufd, 25V	PWP 201.3A	MY
RESISTOR									
R601 thru R606					x	x	CARBON, 4.7K, 1/2W, 5%		STA
R607					x	x	CARBON, 43, 1/2W, 5%		STA
SEMICONDUCTOR									
CR601 thru CR614					x	x	RECTIFIER, 200V, 1.5A	1N4818	WH
TRANSFORMER									
T3					x	x		90-010-90	EL
POTENTIOMETER									
R608					x	x	CERMET, 5K	62P	HP

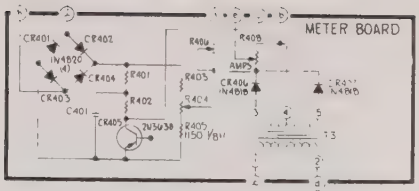


Table 5-9. Meter Board Assembly - Models 1 and 2 only.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
CAPACITOR									
C401	x	x					MYLAR, .47 ufd, 200V	V161	AX
RESISTOR									
R401,R402	x	x					CARBON, 22K, 2W, 5%		STA
R403	x	x					WW, 40K, 3W, 5%	RS2A	DA
R404	x	x					TRIMPOT, 1K	275-1-102	BR
R405	x	x					TIN OXIDE, 1150, 1/8W, 1%	RN60D1151F	CO
R406,R408	x	x					TRIMPOT, 5K	275-1-502	BR
SEMICONDUCTOR									
CR401 thru CR404	x	x					RECTIFIER, 400V, 1A	1N4820	WH
CR405	x	x					TRANSISTOR, 6.2	2N3638	FC
CR406,CR407	x	x					RECTIFIER, 200V, 1A	1N4818	WH
TRANSFORMER									
T3	x	x						90-010-90	EL

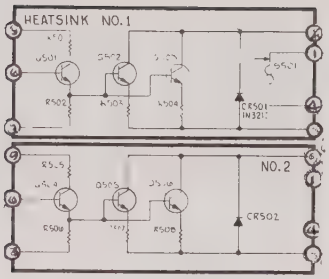


Table 5-10. Power Amplifier Heatsink Assemby - Model 1.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
RESISTOR									
R501,R505	X						WW, 5.6, 5W	AS-5	IR
R502,R506	X						WW, 120, 5W	AS-5	IR
R503,R504 R507,R508	X						WW, .33, 10W, 3%	AS-10	IR
SEMICONDUCTORS									
CR501,CR502	X						RECTIFIER, 200V, 15A	368D	WH
TRANSISTORS									
Q501,Q504 Q502,Q503	X							40250	RCA
Q505,Q506	X							164-09	WH
SWITCH									
S501	X						THERMOSTAT	A505	SO

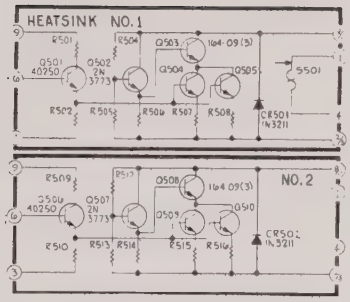


Table 5-11. Power Amplifier Heatsink Assembly - Model 2.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
RESISTOR									
R501.R509		x					WW, 5.6, 5W	AS-5	IR
R502,R507		x					WW, 120, 5W	AS-5	IR
R504,R505, R512,R513		x					WW, 200, 25W		DA
R506,R514		x					WW, 1000, 10W		WL
R507,R508, R515,R516		x					WW, .33, 10W, 3%	AS-10	IR
SEMICONDUCTOR									
CR501,CR502		x					RECTIFIER	1N3211	WH
TRANSISTOR									
Q501,Q506		x						40250	RCA
Q502,Q507		x						2N3773	RCA
Q503,Q504, Q505,Q508, Q509,Q510		x					164-09(3)	6000-164-09	WH
SWITCH									
S501		x					THERMOSTAT	A505	SO

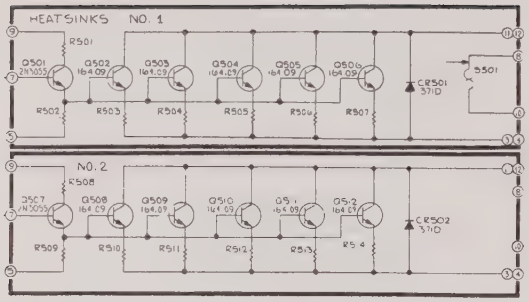


Table 5-12. Power Amplifier Heatsink Assembly - Model 3.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
RESISTOR									
R501,R508			x				WW, 2, 10W	AS-10	IR
R502,R509			x				WW, 50, 10W	AS-10	IR
R503 thru R507,R510 thru R514			x				WW, .33, 10W, 3%	AS-10	IR
SEMICONDUCTOR									
CR501,CR502			x				RECTIFIER, 200V, 15A	1N1186	WH
TRANSISTORS									
Q501,Q507			x					2N3055	RCA
Q502 thru Q506,Q508 thru Q512			x					164-09	WH
SWITCH									
S501			x				THERMOSTAT	A505	SO

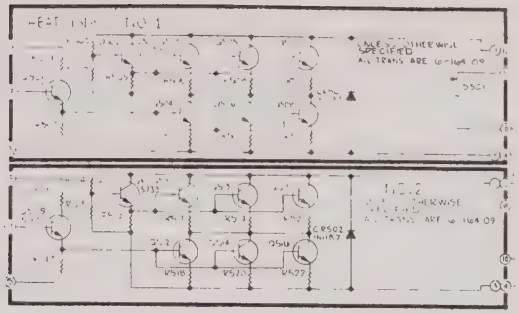


Table 5-13. Power Amplifier Heatsink Assembly - Model 4.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	CODE
RESISTOR									
R501,R512				x			WW, 2, 10W	AS-10	IR
R502,R513				x			WW, 50, 10W	AS-10	IR
R506 thru R511,R517 thru R522				x			WW, .33, 10W, 3%	AS-10	IR
R503,R504, R514,R515				x			WW, 200, 25W	RH-25	DA
SEMICONDUCTOR									
CR501,CR502				x			RECTIFIER, 300V, 15A	1N1187	WH
TRANSISTORS									
Q501,Q509				x				2N3055	RCA
Q503 thru Q508,Q511 thru Q516				x				164-09	WH
Q502,Q510				x				2N3773	RCA
SWITCH									
S501				x			THERMOSTAT	A505	SO

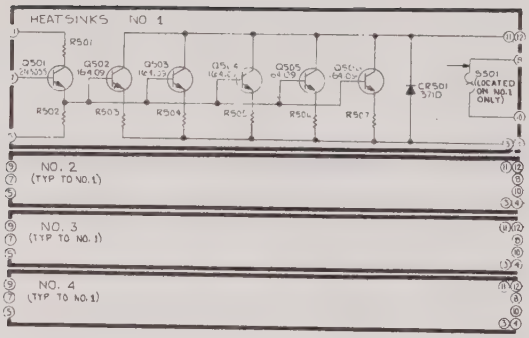


Table 5-14. Power Amplifier Heatsink Assembly - Model 5.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
RESISTOR									
R501,R508					x		WW, 2, 10W	AS-10	IR
R502,R509					x		WW, 50, 10W	AS-10	IR
R503 thru R507,R510 thru R514					x		WW, .33, 10W, 3%	AS-10	IR
SEMICONDUCTOR									
CR501,CR502					x		RECTIFIER, 200V, 35A	1N1186	WH
TRANSISTORS									
Q501,Q507					x			2N3055	RCA
Q502 thru Q506,Q508 thru Q512					x			164-09	WH
SWITCH									
S501					x		THERMOSTAT	A505	SO

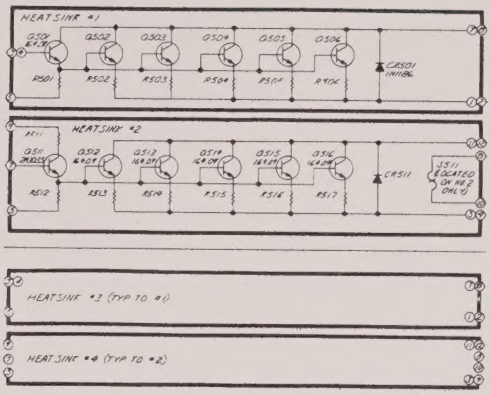


Table 5-15. Power Amplifier Heatsink Assembly - Model 6.

REFERENCE DESIGNATION	MODEL CODE 1	2	3	4	5	6	DESCRIPTION	MANUFACTURER PART NUMBER	MANUFACTURER CODE
RESISTOR									
R501						x	WW, 1K, 10W	AS-10	IR
R502 thru R506						x	WW, .33, 10W, 3%	AS-10	IR
SEMICONDUCTOR									
CR501						x	RECTIFIER, 200V, 35A	1N1186	WH
TRANSISTOR									
Q501 thru Q506						x		164-09	WH
RESISTOR									
R511						x	WW, 2, 10W	AS-10	IR
R512						x	WW, 50, 10W	AS-10	IR
R513 thru R517						x	WW, .33, 10W, 3%	AS-10	IR
SEMICONDUCTOR									
CR511						x	RECTIFIER, 200V, 35A	1N1186	WH
TRANSISTOR									
Q511						x		2N3055	RCA
Q512 thru Q516						x		164-09	WH
SWITCH									
S511						x	THERMOSTAT	A505	SO

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